INVESTIGATION OF THE EFFECT OF INCREASING OF THE TRANSVERSE PHASE VOLUME OF THE BEAM IN AN ELECTRON GUN WITH DIFFERENT COLD CATHODES.

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Abstract

This work is continuation and development of the experimental investigations of found at the accelerator LIA-5/5000 effect the phase volume increasing, which essentially defines the possibility of beam transportation in an accelerating channel. Measurements were carried out at the output of the electron gun E6-430 of the accelerator LIA-5/5000. Two type of plasma desorption slit cathodes and also a velvet catode were investigated. Measurements showed that the type of the cathode and the geometry of the first gap influence only the value of the initial phase volume of the beam V_{ph}. The character of dependence of V_{ph}. upon the function F defining the influence of the space charge of the beam, is the same for all the investigated cathodes that corresponds to the theoretical understanding of the role of space charge in the studied effects.

1. INTRODUCTION

For solving the number of perspective scientific and techical problems high current electrons beams with the energy up to ten's MV and with the brightness exceeding 10^{13}A/cm^2.rad^2 are necessary. Since such beams can be obtained now practicaly only in the linear induction accelerators (LIA) investigations of the problems of the beams generation and acceleration in LIA to receive necessary brightness are very actual. The term "brightness" means - $B = k.I/V^2_{ph}$. So to obtain the high brighness it is necessary to have the proper current I with the minimum phase volume V_{ph}.

The investigations of the last few years pointed out that the currents more than 10 kA may be reached in up-to-date LIA's without any problems. The main difficulty in obtaining of high brightness is phase volume increasing under processes of formation, transportation and acceleration of electrons beams in the LIA. Such increasing is connected with technological feature of the beam transportation like in the case of laser transportation in the ATA accelerator [1], or with the influence of space charge forces in the initial part of the accelerator, which take place in the LIA-5/5000 in ITEP [2].

Earlier [2] it was discovered that if the beam current I exeeded some critical value $I_{cr.}$

$$I \geq I_{cr.} = 0.016\ S\ (\tau - 1)\ \text{kA}, \qquad (1)$$

where S is the cross section area of the beam in the crossover, τ - relativistic factor at the exit of the electron gun (EG), the phase volume of the beam is determined by the expression

$$V = V_0[\ 1 + C\cdot(F - F_{cr.})], \qquad (2)$$

Here V_0 is the phase volume of the beam at the entrance of the acceleration channel, C=30, $F_{cr.}$= 0.0225 - constants for EG of the LIA-5/5000 with the beam diameter 4.6 cm in the crossover. Function $F = F(\tau, I)$ with the accuracy up to 10÷15% is determined as

$$F \simeq \frac{I\cdot\tau\cdot\sqrt{2}}{I_0\cdot(\tau-1)\cdot\sqrt{\tau^2-1}}, \qquad (3)$$

where $I_0 = 2mc/e$ = 17 kA for the electrons, I - beam current. This function is proportional to $S\cdot\delta U/U_0$, where $\delta U/U_0$ is the change of potential in any point on the axis of the accelerator due to space charge of the beam; U_0 - potential in this point without the beam.

The results of the measurements of the dependence of phase volume on the factor F for the beam emitted by desorption slit cathode (DSC) [3] carried out earlier are presented in the Fig. 1. The number of curves were built for the phase volumes corresponding to the different parts $\mathcal{X}$ from the total beam current. Horizontal parts of the curves conformed to the values $F < F_{cr.}$. For $F > F_{cr.}$ the phase volume increased in accordance to equation (2). The values of the phase volume in horizontal parts of the curves concured with the values V_0, i.e. with the phase volume of the

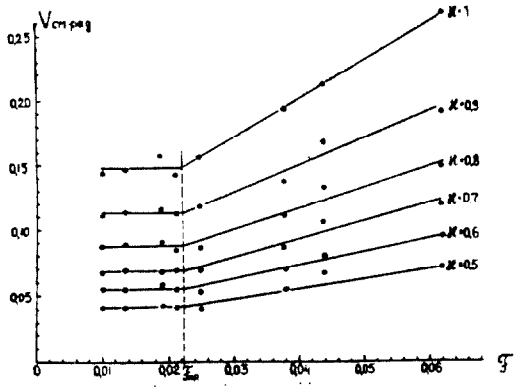

Figure 1. The dependence of the phase volume $V_{ph.}$ on the factor F for the different parts $\mathcal{X}$ from the total beam current. Iris diameter = 4.6 cm.

the beam at the entrance in the acceleration or drift channel. The carried out measurements with DSC cathode for the beams with different diameter showed the constancy of $F_{cr.}/S = 0.0016$ cm^{-2}. So the purpose of this work was investigation of the phase volume increasing for beams emitted by cold cathodes of different types.

2. EXPERIMENT

The measurments of the dependence V(F) have been carried out with the desorption slit cathode (period of the structure: mica - 0.1 mm, copper - 0.3 mm; the height of mica onto the copper surface - 2 mm) and with the velvet piles cathode with the height of the dielectrical elements equals 1.5 mm. In the late case the length of the anode-cathode gap was 30 mm and the optics of the gap was changed by focusing electrode near the cathode in order to reduce the angle spread of particles in the beam. Another DSC with the emitting surface consisted of the 69 separate cells, with an independent current lead each, was also considered.

The investigations were conducted on the exit of the modernized electron gun (EG) of the LIA-5/5000 accelerator (Fig. 2). Improvements in the gun construction provide the arrangement of all axially simetrical current leading elements of the EG on the axis of the accelerator. Higher voltage may be applied to the gap of the newly designed gun and this gave possibility to widen the range of measure-

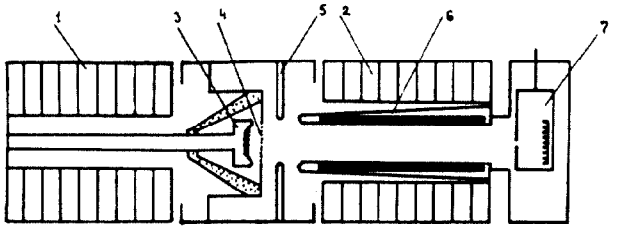

Figure 2. The electron gun EG-430. 1,2 - the first and the second pulse transtformers; 3 - cathode; 4 - grid (first anode); 5 - focusing electrod; 6 - drift tube (second anode); with focusing coil; 7 - phase volume measuring instrument.

ments of $V_{ph.}(F)$ with F as a parameter. In addition the first accelerating gap in the new EG might be changed within one pumping-down cycle.

In experiments being described, just as in the work [2], the lengthes of the first and the second gaps were equal correspondingly 30 and 50 mm, the diameter of the cathodes - 75 mm, the iris diameter - 46 mm. The voltage in the first gap was changed from 100 to 250 kV, in the second gap - from 0 to 400 kV. The emission currents of the cathodes altered from 100 to 1700 A, and the current at the gun exit - from 100 to 500 A.

The modified two slits method was used for phase volume measurements. The device consisted of the entrance slit 0.3 mm and a lamellar system consisting of 20 (40) lamels 0.3 mm width each. This lamellar system was tightly connected with the entrance slit. The distance between the slit and lamellar system was equal 180 mm. Such device had resolution 0.005 cm.rad and it could be moved in the direction transverse to the axis of the beam by a remote control sys-

tem. The signals were registered by oscilloscope with memory and statistical training of the signals was used. Like previous measurements, each point in the V(F) curve corresponded to the minimal value of the focusing magnetic field in the drift channel, when the $V_{ph.}(F)$=const, and there were no losses of the particles.

The initial phase volume of the beam was defined through the results of measurements of the transverse angle spread of the particles in the beam θ for different desorption cathodes [4] and through the diameter of the beam. The value θ was defined by the emission characteristics of a cathode, by the influence of the spherical and chromatic aberrations in the anode - cathode gap and also by the properties of the anode grid. $V_{ph.}$ also depends upon the initial radius of the beam define by the dimension of the iris. The measurements of θ showed at the same time that θ weekly depends upon the pressure of the residual gas in the volume of the EG, upon the moment in the pulse duration, upon the sharpness of accelerating voltage rise in the gap and, at last, upon the value of the accelerating field E_{a-c} itself. The last circumstance is rather essential as any change of the value F under measurement $V_{ph.}(F)$ sometimes requires changes of the accelerating field in the first gap.

3. RESULTS.

The results of the experiments are presented in the fig. 3. The upper curve corresponds to the results of the work [2]. The obtained points for large-structure cell cathode are also pointed in the fig.3. Two lower curves relate to the pile cathode made of velvet. It is seen that the character of the rise of the phase volume is the same for all the different cathodes. Relatively the same slope of the rising parts of the curves supports the conclusion of the work [2] that this slope does not depend upon any other factors except the initial radius of the beam. The values of F_{cr} for all the curves coincide with accuracy to 10%. These facts witness the main factor influencing the rise of

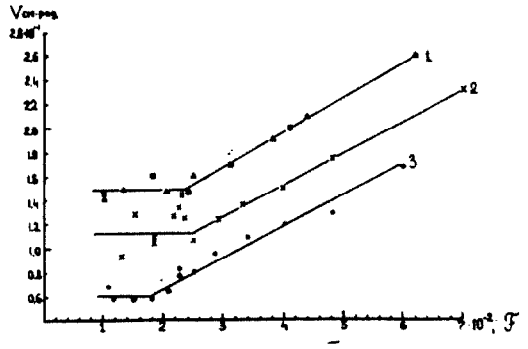

Figure 3. The dependance of the beam phase volume $V_{ph.}$ on factor F for the different types of cathodes. 1 - large-structure mica DSC; 2 - piles cathode (velvet) without focusing electrod; 3 - piles cathode (velvet) with focusing electrod.

the phase volume is the natural space charge of the beam as the factor F depends only upon $\Delta U/U_0$ under constant beam radius. This conclusion does not contradict with the theoretical undestanding of [2].

This investigation confirm the constancy of the ratio $F_{cr.}/S$ = 0.0016 without any dependence upon the gun geometry, type of a cathode and the initial phase volume of the beam.

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